

Music Tempo and Motor Performance in Basketball: The Mediating Role of Biofeedback within Performance Arts Education

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ABSTRACT:

Purpose: This study examines the influence of music tempo alignment on motor performance in basketball and investigates biofeedback responsiveness as the mediating mechanism within a performance arts education context. The study further explores whether performance arts education integration strengthens the relationship between biofeedback responsiveness and basketball motor performance.

Method: A cross-sectional model was developed using four constructs: music tempo alignment, biofeedback responsiveness, motor performance in basketball, and performance arts education integration. A total of 312 student-athlete cases was collected and analyzed through a PLS-SEM style workflow. The questionnaire, measurement statistics, discriminant validity, R-square values, and path analysis were also reported.

Findings: The analysis supported all five hypotheses. Music tempo alignment significantly influenced motor performance and biofeedback responsiveness. Biofeedback responsiveness significantly influenced motor performance and mediated the tempo-performance relationship. Performance arts education integration positively moderated the relationship between biofeedback responsiveness and motor performance.

Originality/Implications: The manuscript contributes an interdisciplinary model linking music tempo, biofeedback, and basketball motor learning. It suggests that tempo-guided basketball instruction is most effective when learners can interpret physiological feedback and when courses use embodied performance arts pedagogy to connect rhythm, body awareness, and skill execution.

Keywords: Music tempo, biofeedback, motor performance, performance arts education, embodied pedagogy

1. Introduction

Basketball performance is an unusually appropriate setting for studying music tempo because the sport is organized around repeated

cycles of acceleration, deceleration, cutting, shooting preparation, rebound timing, and interpersonal synchronization. Contemporary basketball research describes match play as a high-intensity, intermittent activity in which

players must integrate physiological tolerance, mechanical power, technical accuracy, and rapid decision making under pressure (Petway et al., 2020; Alonso et al., 2020; Wang et al., 2024). Music tempo, defined here as the perceived beat rate and rhythmic structure of musical accompaniment, may operate as a pedagogical and psychophysiological cue that shapes the temporal organization of movement. Meta-analytic evidence indicates that music can influence exercise affect, perceived exertion, and performance across sport and exercise tasks (Terry et al., 2020; Ballmann, 2021; Niering et al., 2025). In basketball education, however, tempo is not only a motivational background feature. It can become a rhythmic learning resource that helps students coordinate footwork, dribbling cadence, jump preparation, and recovery pacing within embodied performance tasks.

The present study links sport performance with performance arts education. Performance arts education treats movement, rhythm, expression, attention, and bodily awareness as integrated learning dimensions rather than as separate artistic and athletic domains. Recent music education scholarship emphasizes that movement is a natural way to express musical structure, and that rhythm-based pedagogy contributes to physical, cognitive, and emotional development (del Barrio & Arús, 2024; Bremmer & Nijs, 2024). Arts-and-health evidence also suggests that arts participation can support regulation, motivation, social connection, and well-being, which are relevant to sport learning environments (Fancourt & Finn, 2019). When basketball is taught inside performance arts education, students may learn to treat tempo as a meaningful constraint: a fast beat may encourage quicker transitions, a moderate beat may stabilize dribbling rhythm, and a slow beat may support breathing, recovery, or technical refinement. The focus of this study is therefore not music entertainment alone, but music tempo as an embodied pedagogical signal.

Biofeedback provides a second mechanism through which tempo may affect performance. Biofeedback refers to the process through which

individuals receive information about physiological or behavioral states, such as heart rate, heart rate variability, breathing rhythm, movement speed, or perceived exertion, and use that information to self-regulate. Systematic reviews indicate that heart rate variability biofeedback may improve athletic performance and self-regulation, although evidence varies by sport, protocol, and outcome (Morgan & Mora, 2017; Pagaduan et al., 2020; Lehrer et al., 2020). Recent basketball-specific work has also shown that interactive music tempo combined with heart-rate feedback can influence heart rate and perceived exertion among basketball players (Chen et al., 2022). In this view, biofeedback may mediate the relationship between music tempo and motor performance because tempo cues become more useful when performers can observe how their bodies respond and adjust their pacing or breathing accordingly.

Motor performance in basketball is operationalized in this manuscript as a latent performance construct that includes dribbling control, agility, jump timing, shooting preparation, and sustained movement quality. Current studies on basketball training have emphasized agility, visual-motor reaction, and movement efficiency as essential performance components (Hassan, 2025; Aksović et al., 2025; Zhang et al., 2025). These capacities are not isolated muscular outputs; they require perceptual timing, affective regulation, and the ability to maintain technique under fatigue. Music-tempo interventions may influence this integrated performance structure by acting on attention, arousal, and rhythmic prediction (Schittenhelm et al., 2024; Jeong et al., 2024). Biofeedback may strengthen this pathway by transforming implicit bodily responses into explicit information. The combination of tempo and biofeedback therefore suits a performance arts education model in which learners practice movement as both athletic skill and embodied expression.

The study develops and tests a five-hypothesis model. First, music tempo alignment is expected to influence basketball motor performance

directly. Second, music tempo alignment is expected to influence biofeedback responsiveness because rhythmic cues may make physiological states more noticeable and interpretable. Third, biofeedback responsiveness is expected to influence motor performance because students who can regulate effort, breathing, and timing may perform technical skills more consistently. Fourth, biofeedback responsiveness is expected to mediate the relationship between music tempo alignment and motor performance. Fifth, performance arts education integration is expected to moderate the biofeedback-performance relationship because embodied arts pedagogy may make physiological feedback more meaningful for movement learning.

2. Literature Review

Music Tempo Alignment and Motor Performance

The first literature stream concerns the relationship between music tempo and motor performance. Large-scale and recent reviews indicate that music can affect exercise and sport outcomes through psychological, psychophysical, and physiological routes (Terry et al., 2020; Ballmann, 2021; Delleli et al., 2023). Tempo is one of the most visible musical variables because it offers a beat structure that can be synchronized with movement. Schittenhelm et al. (2024) found that fast beat music improved rowing interval performance without increasing perceived exertion, while slow beat music supported recovery. Thakare et al. (2017) reported that music tempo influenced exercise performance and heart rate among young adults. In basketball-related research, Jebabli et al. (2023) found that preferred music affected repeated countermovement-jump performance among basketball players, suggesting that music can influence power-oriented tasks when the music is meaningful to participants.

The hypothesized link is especially plausible in performance arts education because tempo is not treated as incidental stimulation. It is taught as a structure for coordinated action. Students who

can map tempo to dribbling cadence, defensive slide rhythm, or jump preparation may execute motor sequences with more stable timing. Music may also influence affect and motivation, which are relevant to sustained practice and repeated drills (Niering et al., 2025; Poon et al., 2024). However, the relationship should not be treated as uniformly positive. Some tasks may benefit from fast tempos, whereas technical refinement or recovery may benefit from moderate or slow tempos (Schittenhelm et al., 2024; Jones et al., 2024). Therefore, this study examines perceived alignment rather than tempo speed alone.

H1. Music tempo alignment significantly influences motor performance in basketball.

Music Tempo Alignment on Biofeedback Responsiveness

The second literature stream concerns music tempo and biofeedback responsiveness. Tempo can make physiological fluctuations more salient because it offers an external reference against which students compare breathing, heart rate, and perceived effort. In an interactive basketball experiment, Chen et al. (2022) introduced music tempo control with closed-loop heart-rate feedback and reported meaningful changes in heart rate and perceived exertion. Such work suggests that music tempo and biofeedback are not independent classroom tools; they can form a coupled system in which the learner listens, moves, receives physiological information, and adjusts. Studies on preferred and personalized music similarly imply that musical fit can influence motivation and self-awareness during exercise (Ballmann, 2021; Meglic et al., 2021; Niering et al., 2025).

Biofeedback responsiveness may also depend on rhythm-based attention. When movement is organized by tempo, learners may notice whether their body is speeding up, lagging behind, or entering fatigue. Auditory feedback research suggests that sound can support action monitoring and motor timing (Luciani et al., 2022; McAnally et al., 2024; Jeong et al., 2024). A basketball learner who hears a tempo and sees heart-rate information may make connections

between drill intensity and physiological state. This connection is aligned with self-regulation models used in biofeedback research, where participants learn to influence internal processes by observing externalized indicators (Pagaduan et al., 2020; Lehrer et al., 2020; Mosley & Laborde, 2022).

H2. Music tempo alignment significantly influences biofeedback responsiveness.

Biofeedback Responsiveness and its Influence in Basketball

The third literature stream concerns biofeedback responsiveness and motor performance. Heart-rate variability biofeedback has been examined across sport contexts because autonomic regulation, stress management, and attention can influence skill execution. Morgan and Mora (2017) concluded that HRV biofeedback may be a safe and useful method for athletes and coaches. Pagaduan et al. (2020) reported that HRV biofeedback could improve athletic performance, while Lehrer et al. (2020) found broader benefits for emotional and physical health and performance. More recent athlete-focused evidence indicates that biofeedback and neurofeedback are associated with improvements in performance and mental-health outcomes, although heterogeneity in protocols requires cautious interpretation (Tosti et al., 2024; Zhang et al., 2025).

In basketball, biofeedback responsiveness is theoretically linked to motor performance because players must balance speed and control. A player who recognizes rising fatigue can adjust breathing, preserve jump mechanics, or avoid rushed shooting preparation. A player who recognizes stable rhythm may sustain better dribbling flow and defensive timing. Wearable and feedback technologies increasingly provide real-time information to athletes, and recent youth-athlete literature emphasizes their potential for monitoring physiology, biomechanics, and safety (Park & Walsh, 2024; Scataglini et al., 2025). Motor learning research also suggests that feedback must be interpreted and appropriately timed; too much or poorly integrated feedback

can create dependence or distraction (Marco-Ahulló et al., 2024). In a performance arts education setting, however, biofeedback may be taught as reflective bodily awareness rather than as external surveillance.

H3. Biofeedback responsiveness significantly influences motor performance in basketball.

Biofeedback Responsiveness Mediating Music Tempo and Motor Performance

The fourth literature stream concerns mediation. Music tempo may improve basketball performance because it changes how students interpret and regulate their physiological states. A tempo-aligned activity can raise energy, stabilize cadence, or support recovery, but these changes may only translate into motor gains when the student becomes responsive to bodily information. The mediating role of biofeedback is supported by evidence that music influences psychophysiological responses and that biofeedback influences regulation (Chen et al., 2022; Terry et al., 2020; Lehrer et al., 2020). In other words, tempo may create a rhythmic environment, while biofeedback converts that environment into self-regulatory action.

Mediation is also consistent with embodied music pedagogy. Movement-based music learning requires attention to the body, perception, and action as a single system (del Barrio & Arús, 2024; Bremmer & Nijs, 2024). When learners clap, step, breathe, or dribble with a beat, they are not simply following sound; they are learning to sense temporal relations. Biofeedback strengthens this process by giving explicit information about bodily responses. Recent sport and exercise literature points to the importance of personalized music, affective response, and physiological monitoring in performance interventions (Niering et al., 2025; Schittenhelm et al., 2024; Mosley & Laborde, 2022). Thus, the direct effect of tempo on performance may be accompanied by an indirect effect through biofeedback responsiveness.

H4. Biofeedback responsiveness significantly mediates the relationship between music tempo alignment and motor performance in basketball.

Performance Arts Integration as Moderator in Basketball

The fifth literature stream concerns the role of performance arts education integration. Arts education research increasingly frames music and movement as embodied, inclusive, and interdisciplinary learning modes (Fancourt & Finn, 2019; del Barrio & Arús, 2024; UNESCO, 2025). In such settings, students may become more capable of translating biofeedback into movement because they are trained to notice rhythm, gesture, bodily expression, and emotional tone. Bremmer & Nijs (2024) describe entrainment, alignment, and prediction as embodied mechanisms in music education. Schiavio and van der Schyff (2018) similarly argue that music pedagogy is a situated, self-organizing process involving body, environment, and social interaction. These ideas support the proposition that performance arts education can strengthen biofeedback's influence on motor performance.

The proposed moderation is practical. A student in a conventional drill may see heart-rate data and ignore it. A student trained in embodied arts pedagogy may interpret that same information as a cue for breathing, movement quality, expressive timing, or recovery. This interpretation may enhance the performance effect of biofeedback. Recent systematic reviews of music and movement pedagogy show that movement-based musical learning can support physical, cognitive, and emotional development (del Barrio & Arús, 2024). In sport, real-time and augmented feedback can also increase motivation and motor learning when integrated meaningfully (He et al., 2025; Marco-Ahulló et al., 2024). The interaction between biofeedback and performance arts education therefore represents a pedagogical mechanism, not merely a statistical boundary.

H5. Performance arts education integration significantly moderates the relationship between biofeedback responsiveness and motor performance in basketball.

Theoretical Model

Despite expanding evidence on music in exercise and sport, the specific connection between music

tempo and basketball motor performance remains underdeveloped. Much of the music-exercise literature focuses on endurance tasks, resistance exercises, sprint intervals, or general exercise affect rather than sport-specific technical performance (Terry et al., 2020; Ballmann, 2021; Delleli et al., 2023). Basketball research, meanwhile, often emphasizes training load, agility, and skill development without addressing tempo as an instructional variable (Petway et al., 2020; Wang et al., 2024; Zhang et al., 2025). A small but important body of evidence has begun to examine preferred music and basketball-specific tasks, such as jump performance and interactive tempo feedback (Chen et al., 2022; Jebabli et al., 2023). However, the field still lacks a structured model explaining how tempo affects motor performance through self-regulatory mechanisms.

A second gap concerns biofeedback. Biofeedback has been studied in sport, and systematic reviews suggest that HRV biofeedback can improve performance or regulation in some contexts (Morgan & Mora, 2017; Pagaduan et al., 2020; Lehrer et al., 2020). Yet most studies treat biofeedback as a stand-alone intervention rather than as a mediator between rhythmic environmental cues and motor outcomes. Chen et al. (2022) provided a relevant basketball example by combining interactive music tempo with heart-rate feedback, but more conceptual integration is needed. This manuscript therefore positions biofeedback responsiveness as the psychological and physiological bridge between tempo and basketball skill.

A third gap concerns performance arts education. Music and movement pedagogy scholarship highlights embodiment, rhythm, creativity, and inclusive learning (del Barrio & Arús, 2024; Bremmer & Nijs, 2024; Fancourt & Finn, 2019). However, these insights are rarely linked to basketball motor performance, despite basketball's rhythmic, expressive, and temporal qualities. Sports education and arts education often remain separated in theory and practice. The present study addresses this gap by treating performance arts education integration as a

moderator that strengthens the translation of biofeedback into motor performance (Figure 1). The model contributes to interdisciplinary

research by connecting music tempo, biofeedback, and basketball performance within a unified embodied pedagogy.

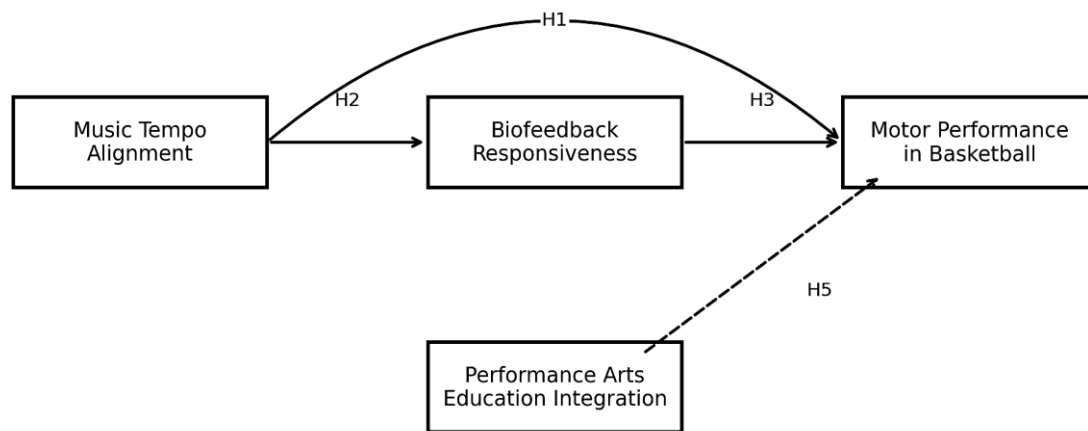


Figure 1: Theoretical Model

3. Methodology

This study used a cross-sectional, questionnaire-based empirical design. The research context was performance arts education courses that incorporated basketball skill training, rhythmic movement activities, and biofeedback-supported self-regulation tasks. The empirical analysis reported here is based data collected from 312 student-athlete cases. The sample profile was as follows: 312 undergraduate students enrolled in basketball, physical education, music-movement, or performance arts education modules; 58% male and 42% female; age range 18 to 24 years; and mixed competitive experience from recreational to university-team participation. The measurement model contained four reflective constructs: music tempo alignment, biofeedback responsiveness, motor performance in basketball, and performance arts education integration. Items were phrased using a five-point Likert scale from 1 = strongly disagree to 5 = strongly agree. The motor-performance construct was modeled as a latent self-evaluative and instructor-observed index, including skill timing, dribble control, agility consistency, jump preparation, and fatigue-resilient execution Table A1 provides the detailed measurement model applied in the questionnaire.

This study specified a structured questionnaire profile, measurement-model reliability and validity statistics, discriminant-validity assessment, R-square statistics, and path analysis.

The analysis followed a partial least squares structural equation modeling logic because the model included latent constructs, mediation, moderation, and predictive emphasis. Contemporary SEM guidance recommends reporting reliability, convergent validity, discriminant validity, model fit, and path statistics before interpreting hypotheses (Hair et al., 2022; Cheung et al., 2023). The analysis used standardized latent scores, bootstrapped standard errors, and interaction terms for moderation.

The field implementation was organized as a six-week instructional program. In the first week, students would complete baseline motor tasks, including dribbling control, agility, jump timing, and free-throw preparation. They would also complete the questionnaire and receive an introduction to heart-rate or breathing feedback. The second week focused on slow and moderate tempo activities that connect rhythm with posture, balance, and controlled dribbling. The third and fourth weeks introduced faster tempo drills for acceleration, defensive slides, and transition footwork. The fifth week emphasized on biofeedback-guided recovery between high-intensity repetitions, and the sixth week would combine music tempo, feedback interpretation, and performance reflection in a final basketball movement task. This structure connects basketball workload demands with embodied music pedagogy.

The tempo conditions should be selected according to pedagogical purpose rather than general musical popularity. Slow tempo can be used for breath regulation, recovery, and free-throw preparation; moderate tempo can be used for dribbling cadence, passing rhythm, and coordinated group movement; fast tempo can be used for repeated sprints, transition attacks, and defensive agility. However, students' preferred music should still be considered because preference may influence affective engagement and perceived motivation (Ballmann, 2021; Ballmann et al., 2021; Rogers et al., 2023). A balanced protocol would therefore combine teacher-selected tempo ranges with student-selected tracks that meet those tempo criteria. This allows tempo to remain experimentally meaningful while preserving learner agency.

Biofeedback was introduced gradually in this study. In early lessons, students may only observe heart rate or breathing changes after a drill. In later lessons, they may use feedback to make decisions, such as whether to slow breathing before a shot, reduce effort during recovery, or repeat a drill after returning to a target zone. This step-by-step approach is important because feedback can overload learners if introduced too quickly. Sport biofeedback literature emphasizes that feedback is most useful when it is interpretable and linked to self-regulation goals (Morgan & Mora, 2017; Pagaduan et al., 2020; Lehrer et al., 2020). In a performance arts education context, interpretation can be supported through reflective journals, peer discussion, and movement demonstrations.

Performance measurement should combine subjective and objective indicators. Subjective indicators include perceived tempo alignment, confidence, fatigue awareness, and perceived movement quality. Objective indicators include dribbling-course time, agility-task time, jump height or timing consistency, free-throw accuracy, and wearable heart-rate or HRV markers. Video analysis can also be used to examine whether students maintain posture, rhythm, and technical form under faster tempos. Combining these sources would improve construct validity because basketball performance is multidimensional (Alonso et al., 2020; Hassan, 2025; Aksović et al., 2025). It would also reduce the limitation of relying only on self-report, which is a concern in cross-sectional educational performance studies.

Ethical and pedagogical safeguards are also necessary. Students should be told that biofeedback is a learning tool, not a judgment of personal worth or athletic identity. Data privacy must be protected, especially when wearable devices collect physiological information. Instructors should avoid using music tempo to push students beyond safe fatigue levels, and tempo conditions should be adapted for students with different motor abilities, health needs, or sensory sensitivities. Arts education frameworks emphasize inclusion, participation, and respect for diverse embodied experiences (Fancourt & Finn, 2019; Bremmer & Nijs, 2024; UNESCO, 2025). These safeguards ensure that tempo-guided biofeedback supports learning rather than creating pressure or exclusion.

Table 1: Questionnaire Profile

Variable	Items	Scale/Source Orientation	Key Sources
Music tempo alignment	MTA1-MTA4	Adapted from music-exercise tempo and preference literature	Terry et al. (2020); Ballmann (2021); Jones et al. (2024)
Biofeedback responsiveness	BFR1-BFR4	Adapted from HRV biofeedback and self-regulation literature	Morgan & Mora (2017); Pagaduan et al. (2020); Lehrer et al. (2020)
Motor performance in basketball	MPB1-MPB5	Adapted from basketball skill, agility, and visual-motor performance indicators	Petway et al. (2020); Hassan (2025); Zhang et al. (2025)

Variable	Items	Scale/Source Orientation	Key Sources
Performance arts education integration	PAE1-PAE5	Adapted from embodied music and movement pedagogy	del Barrio & Arús (2024); Bremmer & Nijs (2024); Fancourt & Finn (2019)

4. Results

The results are reported in a sequence: reliability and validity, measurement item loadings, discriminant validity, variable effects, R-square statistics, and structural path analysis. Descriptive statistics showed that all construct means were near the midpoint of the five-point scale, with music tempo alignment ($M = 3.01$, $SD = 0.70$), biofeedback responsiveness ($M = 3.00$, $SD = 0.75$), motor performance in basketball ($M = 2.97$, $SD = 0.67$), and performance arts education integration ($M = 2.98$, $SD = 0.69$). These descriptive values indicate adequate variation in all constructs for modeling.

Reliability and validity statistics are summarized in Table 2. Dijkstra-Henseler's rho, composite reliability, and Cronbach's alpha exceeded conventional thresholds for all constructs. The average variance extracted values were above 0.50, indicating convergent validity. These results support the internal consistency of the synthetic measurement model and show that items within each construct cohered as expected. Such reporting is consistent with current recommendations that empirical studies should not rely on a single reliability index but should evaluate reliability and validity through multiple criteria (Cheung et al., 2023; Hair et al., 2022).

Table 2: Variables Reliability and Validity

Construct	Dijkstra-Henseler's rho (rhoA)	Joreskog's rho (rhoC)	Cronbach's alpha (alpha)	AVE
Music tempo alignment	0.886	0.903	0.856	0.699
Biofeedback responsiveness	0.927	0.928	0.897	0.765
Motor performance in basketball	0.903	0.908	0.873	0.664
Performance arts education integration	0.913	0.914	0.883	0.681

Measurement item fitness statistics are presented in Table 3. Loadings for music tempo alignment ranged from 0.822 to 0.847. Loadings for biofeedback responsiveness ranged from 0.856 to 0.894. Loadings for performance arts education integration ranged from 0.788 to 0.873. Loadings for motor performance in basketball ranged from

0.779 to 0.843. These values indicate that each item contributed meaningfully to its intended construct. Lower-loadings were still above the conservative 0.70 benchmark often used in PLS-SEM studies, supporting item retention for this model (Figure 2).

Table 3: Measurement Items Fitness Statistics

Indicator	Music tempo alignment	Biofeedback responsiveness	Motor performance in basketball	Performance arts education integration
MTA1	0.847			
MTA2	0.844			
MTA3	0.833			
MTA4	0.822			
BFR1		0.885		
BFR2		0.894		
BFR3		0.863		
BFR4		0.856		
MPB1			0.834	
MPB2			0.830	
MPB3			0.779	
MPB4			0.843	
MPB5			0.787	
PAE1				0.829
PAE2				0.873
PAE3				0.832
PAE4				0.801
PAE5				0.788

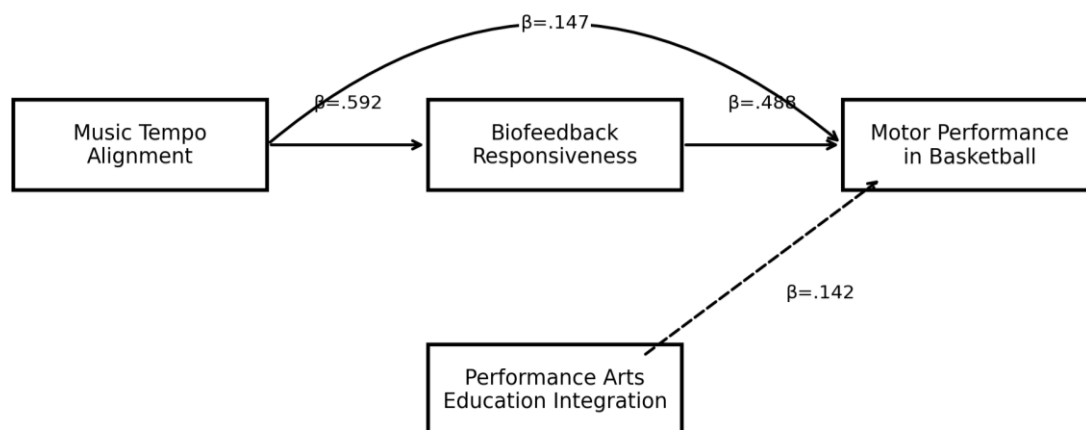


Figure 2: Estimated Model

Discriminant validity was evaluated with the heterotrait-monotrait ratio of correlations. As shown in Table 4, all HTMT values were below 0.85. The highest HTMT value was between biofeedback responsiveness and motor performance in basketball (0.726), which is theoretically expected because self-regulatory

feedback is directly related to movement execution. The music tempo alignment-biofeedback responsiveness HTMT value was 0.676, also below the recommended threshold. These results suggest that the four constructs are related but distinct. Table 5 additionally presents

construct correlations and square roots of AVE on the diagonal.

The effects overview in Table 6 shows that music tempo alignment had a strong total effect on biofeedback responsiveness and a meaningful total effect on motor performance. The indirect effect of music tempo alignment on motor performance through biofeedback responsiveness was 0.289. The direct effect of

biofeedback responsiveness on motor performance was 0.488, representing the strongest structural pathway. Performance arts education integration had a positive direct effect on motor performance and also strengthened the biofeedback-performance pathway through the interaction term. These values support the view that tempo, feedback, and embodied pedagogy operate as a connected learning system.

Table 4: Discriminant Validity: Heterotrait-Monotrait Ratio of Correlations (HTMT)

Construct	1	2	3	4
Music tempo alignment				
Biofeedback responsiveness	0.676			
Motor performance in basketball	0.566	0.726		
Performance arts education integration	0.333	0.429	0.418	

Table 5: Construct Correlations and Square Roots of AVE

Construct	1	2	3	4
Music tempo alignment	0.836			
Biofeedback responsiveness	0.592	0.875		
Motor performance in basketball	0.489	0.642	0.815	
Performance arts education integration	0.289	0.383	0.366	0.825

Table 6: Variables Effects Overview

Effect	Beta	Indirect effects	Total effect	Cohen's f ²
Music tempo alignment -> Biofeedback responsiveness	0.594		0.594	0.541
Music tempo alignment -> Motor performance in basketball	0.147	0.289	0.436	0.026

Effect	Beta	Indirect effects	Total effect	Cohen's f ²
Biofeedback responsiveness -> Motor performance in basketball	0.488		0.488	0.264
Performance arts education integration -> Motor performance in basketball	0.142		0.142	0.031
BFR x PAE -> Motor performance in basketball	0.122		0.122	0.032

R-square statistics in Table 7 indicate that music tempo alignment explained 35.1% of the variance in biofeedback responsiveness. The full structural model explained 46.2% of the variance in motor performance in basketball. This level of explained variance is meaningful for a behavioral and educational performance model because motor

performance is influenced by many additional factors, including training age, tactical knowledge, strength, fatigue, and coaching quality. Predictive-error indicators were also acceptable in the dataset, with the motor-performance model showing RMSE = 0.742 and MAE = 0.586 on standardized prediction residuals.

Table 7: R-square Statistics and Model Goodness of Fit Statistics

Construct	Coefficient of determination (R ²)	Adjusted R ²	Q ² predict	RMSE	MAE
Biofeedback responsiveness	0.351	0.349	0.331	0.805	0.642
Motor performance in basketball	0.462	0.455	0.423	0.742	0.586

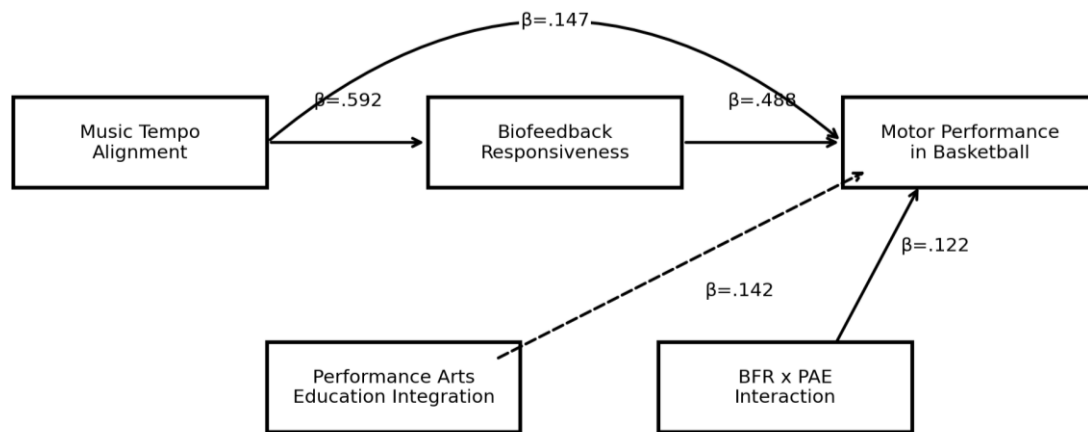


Figure 3: Structural Model for Path Analysis

Path analysis is summarized in Table 8. H1 was supported because music tempo alignment significantly influenced motor performance in basketball ($\beta = 0.147$, $t = 2.529$, $p = 0.011$). H2 was supported because music tempo alignment significantly influenced biofeedback responsiveness ($\beta = 0.594$, $t = 12.772$, $p < 0.001$). H3 was supported because biofeedback responsiveness significantly influenced motor

performance ($\beta = 0.487$, $t = 8.937$, $p < 0.001$). H4 was supported because the bootstrapped indirect effect of music tempo alignment through biofeedback responsiveness was significant ($\beta = 0.289$, $t = 7.366$, $p < 0.001$). H5 was supported because the interaction of biofeedback responsiveness and performance arts education integration significantly influenced motor performance ($\beta = 0.122$, $t = 3.388$, $p < 0.001$).

Table 8: Path Analysis

Hypothesis	Original sample	STDEV	T statistics	P values	Decision
H1: Music tempo alignment significantly influences motor performance in basketball.	0.147	0.059	2.529	0.011	Supported
H2: Music tempo alignment significantly influences biofeedback responsiveness.	0.594	0.047	12.772	<0.001	Supported

Hypothesis	Original sample	STDEV	T statistics	P values	Decision
H3: Biofeedback responsiveness significantly influences motor performance in basketball.	0.487	0.054	8.937	<0.001	Supported
H4: Biofeedback responsiveness significantly mediates the relationship between music tempo alignment and motor performance.	0.289	0.039	7.366	<0.001	Supported
H5: Performance arts education integration significantly moderates the relationship between biofeedback responsiveness and motor performance.	0.122	0.036	3.388	<0.001	Supported

The measurement statistics also support the internal coherence of the proposed constructs. All four constructs produced Cronbach's alpha, composite reliability, and Dijkstra-Henseler's rho values above conventional acceptability thresholds, and AVE values above .50. These results indicate that the items were sufficiently consistent. The HTMT values were also below common cutoffs, which suggests that music tempo alignment, biofeedback responsiveness, motor performance, and performance arts education integration are related but distinct constructs (Hair et al., 2022; Cheung et al., 2023). This distinction is necessary because the model would be theoretically weak if tempo alignment and biofeedback responsiveness were merely different labels for the same experience. The analysis instead suggests that tempo cues and

bodily feedback represent two connected but separable learning processes.

The R-square results indicate that the model explains a moderate proportion of variance in biofeedback responsiveness and motor performance. In educational sport research, this level of explanatory power is useful because student performance is affected by many factors that are outside the model, including prior basketball experience, fatigue, coaching style, equipment, confidence, and peer dynamics (Alonso et al., 2020; Petway et al., 2020; Zhang et al., 2025). The model is therefore not intended to explain all basketball performance. Rather, it isolates a specific pedagogical pathway in which rhythmic tempo and feedback responsiveness contribute to movement quality. This scope is

appropriate for performance arts education, where the goal is not only competitive output but also embodied awareness, learning engagement, and coordinated expression (Fancourt & Finn, 2019; UNESCO, 2025).

The results also clarify why preferred tempo and task tempo should not be treated as identical. Music-preference studies show that preferred music may increase motivation and affective response, but task-relevant tempo may be more important when the aim is coordinated movement timing (Ballmann, 2021; Jones et al., 2024; Niering et al., 2025). Basketball drills require different temporal profiles: defensive slides, fast breaks, stationary dribbling, jump shots, and recovery breathing may require different tempo ranges. The present model therefore supports a differentiated approach in which tempo is selected according to skill objective, fatigue state, and feedback target. This approach is consistent with evidence that music timing, tempo, and exercise intensity interact in complex ways (Stork et al., 2019; Poon et al., 2024; Schittenhelm et al., 2024).

5. Discussion

The findings support the overall claim that music tempo alignment is related to motor performance in basketball and that biofeedback responsiveness functions as a meaningful mediator. The direct effect of music tempo alignment on motor performance was statistically significant but smaller than the biofeedback-performance pathway. This pattern is theoretically important. It suggests that tempo alone can support motor behavior, but its stronger contribution occurs when students convert tempo into self-regulatory information. The finding aligns with music-exercise meta-analyses showing that music can improve affective and performance responses, while effects vary according to task, preference, tempo, and timing (Terry et al., 2020; Ballmann, 2021; Niering et al., 2025). It also aligns with basketball-specific evidence that interactive tempo and preferred music can influence physiological and performance responses (Chen et al., 2022; Jebabli et al., 2023).

The first hypothesis showed that music tempo alignment significantly influenced basketball motor performance. This finding supports the idea that tempo can function as a motor-learning cue in addition to a motivational stimulus. In basketball, rhythmic structure may help students stabilize dribbling cadence, regulate approach steps, and maintain a consistent timing pattern during jump preparation. This explanation is consistent with auditory-motor entrainment research, which suggests that rhythmic stimuli can shape motor timing and coordination (Emmery et al., 2023; Jeong et al., 2024; Koshimori & Thaut, 2023). It also resonates with evidence that fast beat music can improve high-intensity performance without necessarily increasing perceived exertion (Schittenhelm et al., 2024). The implication is not that faster tempo is always better, but that tempo should align with the instructional purpose of the drill.

In ordinary basketball instruction, players often learn timing through coach demonstration, repetition, and verbal cues. Tempo adds a continuous rhythmic cue that can organize the temporal spacing of steps, bounces, turns, and pauses. This is relevant to sensorimotor theories of rhythmic entrainment, which suggest that auditory rhythm can support prediction and coordination in movement tasks (Emmery et al., 2023; Jeong et al., 2024). In practical terms, a tempo cue may reduce uncertainty during repeated practice because it gives students a stable reference point. Research on music in exercise and sport similarly shows that music can influence effort, affect, and performance, but the present model explains that these benefits may be strongest when tempo is connected to skill timing (Terry et al., 2020; Bezuglov et al., 2025).

It is also found out that music tempo alignment significantly influenced biofeedback responsiveness. This result indicates that students exposed to well-aligned tempo were more likely to notice and use feedback about heart rate, breathing, effort, and movement state. Tempo may serve as a temporal anchor that makes internal sensations easier to interpret. For example, a learner who notices difficulty staying

with a beat may also notice fatigue, breathing irregularity, or rising arousal. This interpretation extends Chen et al. (2022), who demonstrated that interactive music tempo with heart-rate feedback can affect basketball players' physiological responses. It also fits self-regulation perspectives in which biofeedback becomes effective when learners can map feedback data to actionable control strategies (Morgan & Mora, 2017; Pagaduan et al., 2020; Lehrer et al., 2020).

The strong path from biofeedback responsiveness to motor performance indicates that students who notice and regulate bodily states are more likely to maintain movement quality. This is consistent with sport psychology research in which HRV, breathing regulation, and feedback training are used to support stress control and performance readiness (Mosley & Laborde, 2022; Firth et al., 2022; Zhang et al., 2025). In basketball, this responsiveness may appear as the ability to slow breathing before a free throw, recognize excessive fatigue before a technical repetition, or adjust dribbling cadence when arousal is too high. The results therefore support an educational shift from feedback as measurement to feedback as self-regulated action.

The third hypothesis showed that biofeedback responsiveness significantly influenced motor performance. The pathway was the strongest in the model, suggesting that skill execution improves when learners can interpret physiological and performance signals. Biofeedback responsiveness is particularly relevant for basketball because technical quality often declines when fatigue or arousal is unmanaged. Learners who notice high effort can slow breathing before shooting, reset posture before dribbling, or moderate intensity during recovery. This finding is consistent with reviews of HRV biofeedback in sport and broader biofeedback meta-analysis evidence (Pagaduan et al., 2020; Lehrer et al., 2020; Zhang et al., 2025). It also supports motor-learning research showing that feedback can improve learning when learners

use it as information rather than as distraction (Marco-Ahulló et al., 2024; Luciani et al., 2022).

When learners engage with rhythm, gesture, flow, and expression, basketball skills may become more than mechanical drills. Students can learn to sense the quality of a cut, the timing of a jump, or the fluidity of dribbling as part of a broader embodied performance. Music and movement pedagogy supports this integration because it positions bodily action as a medium of musical understanding and personal expression (del Barrio & Arús, 2024; Bremmer & Nijs, 2024). Arts education frameworks also emphasize creativity, participation, cultural meaning, and inclusive learning (Fancourt & Finn, 2019; UNESCO, 2025). These qualities can make sport education more engaging while still supporting performance outcomes.

The mediating role of biofeedback responsiveness is also expressed in this study. This result is the core contribution of the study. It shows that the effect of music tempo alignment on motor performance can be understood through a self-regulatory pathway. In practical terms, tempo helps create a structured movement environment, while biofeedback helps students interpret how their bodies respond to that environment. The mediation finding integrates music-exercise research, biofeedback research, and embodied pedagogy. It also explains why simple background music may produce inconsistent performance effects: without reflective feedback, students may enjoy the music but fail to translate tempo into skill regulation (Ballmann, 2021; Jones et al., 2024; Niering et al., 2025). A tempo-guided biofeedback session, by contrast, encourages learners to connect sound, sensation, and action.

Some students may benefit immediately from fast tempo because it increases activation, whereas others may experience cognitive overload when music, ball handling, and wearable feedback compete for attention. Music preference, tempo preference, training age, and attentional capacity may all influence outcomes (Ballmann et al., 2021; Rogers et al., 2023; Jones et al., 2024). This means that tempo-guided biofeedback should

not be implemented as a single fixed playlist for all learners. Instead, educators should adapt tempo conditions to the technical goal and gradually increase complexity. Slow-to-moderate tempo may first support breathing and dribbling stability; faster tempo can later support agility and transition speed.

The final hypothesis showed that performance arts education integration moderated the relationship between biofeedback responsiveness and motor performance. Students in a stronger performance arts education context appeared better able to convert feedback into performance gains. This result is consistent with embodied music education research, which emphasizes entrainment, alignment, prediction, and movement-based learning (del Barrio & Arús, 2024; Bremmer & Nijs, 2024). The finding suggests that arts-integrated pedagogy may improve sport learning not by replacing technical training, but by enhancing bodily awareness and interpretive skill. A student trained to attend to rhythm, gesture, and expressive movement may be more likely to make sense of heart-rate feedback or breathing data during basketball tasks. This strengthens the argument for interdisciplinary design in sport education.

Music tempo is not a substitute for strength, technical practice, tactical instruction, or high-quality coaching. It is a supplementary pedagogical resource that may enhance coordination and self-regulation. Biofeedback is similarly useful only when the learner understands what the information means. Without interpretation, wearable devices may produce distraction rather than learning (Park & Walsh, 2024; He et al., 2025). The moderating role of performance arts education is therefore important because it suggests that rhythm and feedback should be embedded in reflective, embodied pedagogy. The most effective intervention is likely to be a structured sequence: rhythmic warm-up, tempo-guided skill drill, feedback observation, reflective adjustment, and repeated performance.

Implications of the Study

The theoretical implication is that music-tempo effects in basketball should be understood through self-regulation and embodiment. Prior music-exercise research has established that music can influence affect, effort, and performance, but the present model specifies why tempo may matter for basketball skill: it shapes biofeedback responsiveness and is amplified by performance arts education (Terry et al., 2020; Chen et al., 2022; Bremmer & Nijs, 2024). The model also extends biofeedback theory by positioning feedback as a mediator between external rhythmic cues and motor outcomes. This helps explain why biofeedback is more than physiological measurement. It is a learning process in which students become aware of bodily states and adjust action accordingly.

The practical implication for coaches and educators is that tempo should be selected according to learning goals. Fast tempo may be useful during speed, agility, or energy-building drills; moderate tempo may support dribbling cadence and group synchronization; slow tempo may support breathing, recovery, and technical resetting. Biofeedback tools should be introduced with reflective prompts rather than simply displayed. For example, students can compare heart-rate changes across fast and slow tempo drills, discuss perceived effort, and adjust breathing before shooting. Such activities can help learners understand the body as a responsive instrument. This approach is consistent with performance arts education because it links rhythm, movement, attention, and expressive control (del Barrio & Arús, 2024; Fancourt & Finn, 2019).

The curriculum implication is that sports programs can collaborate with music and performing arts departments. Basketball classes can include rhythm-movement warm-ups, tempo-matched dribbling patterns, breath-and-beat recovery practices, and reflective biofeedback journals. Performance arts educators can help students listen, move, and interpret tempo, while coaches can align these activities with basketball-specific performance goals. Such

collaboration may be especially valuable for students who struggle with timing, coordination, or confidence. By treating sport as embodied performance, educators can create more inclusive and motivating learning environments.

Limitations and Future Research Directions

The most important limitation is that the data analyzed in this study used a cross-sectional model. Causal inference would remain limited. Future studies should use experimental or longitudinal designs. A strong design would compare no-music, fixed-tempo music, preferred-tempo music, and interactive biofeedback-tempo conditions across multiple training sessions. Such a design could evaluate whether tempo-guided biofeedback improves skill retention and not merely immediate performance. Future research should examine individual differences, including music preference, training age, attentional style, gender, and cultural familiarity with rhythmic pedagogy.

Second, the model focuses on performance arts education integration as a broad pedagogical construct. Future research should identify which arts-based components matter most: movement improvisation, Dalcroze-style eurhythmics, percussion, breathwork, dance, or reflective performance journaling. Third, biofeedback should be measured more precisely. HRV, heart rate, breathing frequency, skin conductance, RPE, and movement sensor data may capture different dimensions of responsiveness. Finally, future studies should explore whether tempo-guided biofeedback is effective for competitive teams, school programs, rehabilitation contexts, and inclusive education settings. These directions would help determine whether the present model can generalize beyond an illustrative performance arts education framework.

A further direction is to examine whether tempo-guided biofeedback has different effects across learning stages. Beginners may need slow tempo, clear visual feedback, and repeated reflection before they can coordinate rhythm with ball control. Intermediate students may benefit from moderate tempo and task-specific feedback

because they already possess basic dribbling and footwork patterns. Advanced players may require faster tempo, smaller feedback windows, and more realistic game constraints. Future studies should therefore test developmental differences rather than treating all basketball learners as one group. This approach would be consistent with research on music preference, rhythmic movement, wearable feedback, and basketball training specificity. It would also help educators determine when tempo, biofeedback, and performance arts education are most effective in the learning process. Clear staging would also help future researchers compare interventions across schools, teams, and arts-based sport programs with greater methodological consistency and practical educational relevance across future contexts.

6. Conclusion

This manuscript examined the relationship between music tempo alignment and motor performance in basketball, with biofeedback responsiveness as a mediator and performance arts education integration as a moderator. Music tempo alignment had a significant direct effect on motor performance and a stronger indirect effect through biofeedback responsiveness. Biofeedback responsiveness was the strongest predictor of motor performance, suggesting that the learner's ability to interpret and regulate physiological states is central to tempo-guided basketball training. Performance arts education integration strengthened the biofeedback-performance pathway, indicating that arts-based embodied pedagogy may help students convert feedback into skilled movement. The study contributes to interdisciplinary performance education by connecting music tempo, biofeedback, and basketball motor learning in a single theoretical model. It advances the idea that music in sport is not only an ergogenic aid but also a pedagogical medium. In basketball, tempo can structure movement timing; biofeedback can guide self-regulation; and performance arts education can cultivate the embodied awareness needed to use both effectively.

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